The Unit of Chemistry Teacher Education
Department of Chemistry
University of Helsinki

TOWARDS LEARNER-DRIVEN SCIENCE TEACHER EDUCATION FOR SUSTAINABILITY

Jaana Herranen

DOCTORAL DISSERTATION

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ABSTRACT

As the world is constantly changing, and there are concerns over a sustainable future, educating teachers for sustainability is crucial, as education is one of the most effective means to improve sustainability. Science, such as chemistry, plays a significant role in addressing sustainability issues, because chemistry can contribute to both solving as well as causing the challenges through knowledge and products that chemistry produces. Science and sustainability are inherently connected, as are the discussions over their education. On both these fields, discussions over the role of the students have emerged. In science education there has been a growing interest to educate scientifically literate students who can use scientific thinking in their own lives and in the society. This requires active participation of the students in their own learning. Sustainability education has been advocating transformative learning so that students could take action in their own lives towards sustainability. Moreover, teacher education could be developed in a direction in which the student teachers would be given possibilities to make decisions concerning the learning and teaching methods used and contents chosen, and develop their action-competence through active participation. However, in order to reach sustainability, all citizens should be considered as learners, not only students in schools and universities. Discussion over the learners' roles has led to the using of terms, such as learner-centred and learner-driven learning. What these terms actually entail is, however, not always clear. In science education, learner-driven approaches are usually practiced in the form of open inquiry – an inquiry that starts with the students' questions. Addressing and using the students' questions is important in science education, but also in sustainability education to activate learners to think and act for sustainability.

The aim of this thesis is to understand the possibilities and challenges of learner-centred and learner-driven science teacher education for sustainability. The research questions are: i) Which possibilities do learner-centred and learner-driven science teacher education for sustainability offer? and ii) What are the challenges for learner-centred and learner-driven science teacher education for sustainability? For this purpose, two types of approaches are studied: inquiry-based education as a typical approach in science teacher education from the point of view of learner-centred and learner-driven inquiry, and sustainability education as a part of science teacher education for sustainability from the viewpoint of learner-centred and learner-driven sustainability education. This is a qualitative multi-method research with one systematic review and three case studies applying grounded theory and discourse analysis. The thesis consists of four articles: i) Inquiry as a context-based practice – A case study of pre-service teachers' beliefs and implementation of inquiry in context-based science teaching ii) Student-question-based inquiry in science education, iii) From learner-centred to

learner-driven sustainability education, and iv) Challenges and tensions in collaborative planning of a student-led course on sustainability education.

Data for the studies was derived from three sources including higher education student groups and peer-reviewed articles. Study I utilised data from five student teachers who participated in a course "inquiry-based chemistry teaching" in 2015. Their beliefs about inquiry were studied by interviewing them, and their implementations of inquiry were studied from their reports. Data in study II consisted of 30 articles reviewed using systematic review. In studies III and IV, the research data consisted of a planning process of higher education students (student teachers and students interested in teaching) who planned and ran a course "sustainable development in education" in 2015. Their planning meetings and two semi-structured interviews were analysed using discourse analysis and grounded theory.

As a result, understanding on the differences between learner-centred and learner-driven sustainability education was obtained. This thesis reveals that learner-driven and learner-centred education are different constructs, especially related to the learners' roles. Student-led planning on sustainability education was studied to be challenging, as the students had to discuss several interrelated issues on sustainability and sustainability education, as well as their own roles and ways to work as a group. However, the challenges in learner-driven approaches can sometimes be viewed as part of the process. In addition, possibilities for learner-centred and learner-driven practices were revealed on how to use students' questions in inquiries and contexts-based inquiry as a humanistic approach. For science education, a student-question-based inquiry model was created, which the teacher can use to support students in their question asking. The study also revealed challenges related to the ownership of students' questions.

The results from this thesis are relevant when planning teacher education for sustainability. This thesis points out that especially higher education has the potential to involve the students more in teaching by promoting action-competence among students through learner-driven education. Science teacher education could be focusing more on using learner-centred and learner-driven approaches, because the studied higher education students could plan and carry out teaching that mirror central aspects of science and sustainability education. Moreover, in order to be able to use learner-driven approaches, there is a need to use extra-situational knowledge, to improve students' ownership of their own questions, to redefine expertise, and to work with non-predefined goals and with the whole community.

TIIVISTELMÄ

Opettajankoulutus on yksi tärkeimmistä keinoista kestävän tulevaisuuden rakentamisessa. Opetukseen tarvitaan uusia tutkimuspohjaisia kestävyyskasvatuksen malleja. Koska kestävyyshaasteet ovat monimutkaisia, niiden ratkaisemiseksi tarvitaan monitieteellisiä lähestymistapoja. Myös luonnontieteiden opetuksessa voitaisiin huomioida enemmän kestävyyskasvatuksen näkökulmia. Luonnontieteet, kuten kemia voidaan nähdä sekä haasteiden aiheuttajana, että niiden ratkaisijana. Lisäksi kestävyyskasvatusta voitaisiin kehittää oppijoita osallistavaan suuntaan, jossa oppijat saisivat enemmän mahdollisuuksia tehdä omaa opiskelua ja opetusta koskevia päätöksiä. Nämä oppijoita osallistavat ja aktioivat taidot ovat erityisen tärkeitä tuleville opettajille, jotta he pystyvät hyödyntämään osaamistaan tulevassa työssään. Oppijakeskeisiä ja -lähtöisiä oppimismahdollisuuksia on näin ollen tarpeellista kehittää ja tutkia kemian opettajankoulutuksessa. Aiemmissa tutkimuksissa on tutkittu oppijakeskeisiä lähestymistapoja, joissa oppilas huomioidaan eri tavoin opetuksessa. Luonnontieteiden opetuksessa oppijalähtöisyyttä käytetään tyypillisesti avoimessa tutkimuksellisuudessa, joka on oppilaiden kysymyksistä lähtevää tutkimuksellisuutta. On todettu, että opetuksessa voitaisiin hyödyntää nykyistä enemmän oppilaiden kysymyksiä, joten tähän tarvitaan erilaisia malleja.

Tutkimuksen päämääränä on ymmärtää, mitä mahdollisuuksia ja haasteita kestävyyteen tähtäävään oppijakeskeiseen ja oppijalähtöiseen luonnontieteiden opettajakoulutukseen liittyy. Tutkimuskysymykset ovat: i) Mitä mahdollisuuksia kestävyyteen tähtäävä oppijakeskeinen ja oppijalähtöinen luonnontieteiden opettajakoulutus tarjoaa? ja ii) Mitkä ovat oppijakeskeisen ja oppijalähtöisen kestävyyteen tähtäävän luonnontieteiden opettajakoulutuksen haasteet? Tutkimus on laadullinen monimenetelmätutkimus, joka koostuu yhdestä systemaattisesta katsauksesta ja kolmesta tapaustutkimuksesta, joissa käytetään grounded theorya ja diskurssianalyysiä. Väitöstutkimus koostuu neljästä artikkelista: i) Inquiry as a context-based practice – A case study of pre-service teachers` beliefs and implementation of inquiry in context-based science teaching ii) Student-question-based inquiry in science education, iii) From learner-centred to learner-driven sustainability education, and iv) Challenges and tensions in collaborative planning of a student-led course on sustainability education.

Tutkimuskohteena on opiskelijaryhmiä, jotka koostuivat pääosin opettajaopiskelijoista (tutkimukset I, III ja IV) sekä vertaisarvioituja artikkeleita (tutkimus II). Tutkimuksessa I on käytetty tutkimusaineistona viiden kemian opettajaopiskelijan haastatteluja sekä raportteja heidän osallistuttuaan kurssille ”tutkimuksellinen kemian opetus” vuonna 2015. Tutkimuksessa on selvitetty opettajaopiskelijoiden uskomuksia

tutkimuksellisuudesta sekä heidän tapojaan toteuttaa kontekstuaalista tutkimuksellisuutta. Tutkimuksessa II on tutkittu 30 vertaisarvioitua artikkelia oppilaiden kysymyslähtöisestä tutkimuksellisuudesta käyttäen tutkimusmenetelmänä systemaattista katsausta. Tutkimuksessa III ja IV on käytetty tutkimusaineistona opiskelijaryhmän taltioitua suunnitteluprosessia heidän suunnitellessaan kurssia ”kestävä kehitys opetuksessa” vuonna 2015.

Väitöskirjassa esitetään, että oppijakeskeisen ja oppijalähtöisen kestävän kehityksen opetuksen lähtökohdat ovat erityisesti oppijan roolin näkökulmasta erilaiset. Tulosten perusteella opetuksen suunnittelu voi olla opiskelijoille haastavaa, vaikka toisiaan haasteet voidaan nähdä osana prosessia. Kestävän kehityksen opetuksen kurssia suunnitellessaan opiskelijoiden oli keskusteltava useasta toisiinsa kytkeytyneestä kestävyyden ja kestävyyskasvatuksen näkökulmasta sekä omasta roolistaan ja työskentelystään ryhmänä. Lisäksi oppijakeskeisten ja oppijalähtöisten lähestymistapojen mahdollisuuksiksi havaittiin oppijoiden omien kysymysten käyttö tutkimuksellisuuden lähtökohtana ja humanistinen näkökulma toteuttaa kontekstuaalista tutkimuksellisuutta. Tutkimuksessa kehitettiin myös malli luonnontieteiden opetukseen, joka kuvaa, miten opettaja voi toteuttaa opetuksessaan oppilaiden kysymyksistä lähtevää tutkimuksellisuutta. Tutkimus paljasti myös mallin haasteet liittyen kysymysten omistajuuteen.

Tämän väitöskirjan tuloksia voidaan huomioida suunniteltaessa kestävyyteen tähtäävää kemian opettajankoulutusta. Tässä väitöskirjassa esitetään, että erityisesti korkeakouluopetuksessa voidaan osallistaa opiskelijoita tukemalla heidän toimijuuttaan oppijalähtöisten lähestymistapojen kautta. Luonnontieteiden opettajankoulutusta voisi suunnata kohti oppijakeskeisiä ja oppijalähtöisiä lähestymistapoja, koska tutkitut korkeakouluopiskelijat pystyivät suunnittelemaan ja toteuttamaan sellaista opetusta, joka ilmensi tutkimuksellisen luonnontieteiden opetuksen ja kestävän kehityksen opetuksen keskeisiä näkökulmia. Oppijalähtöisyys edellyttää kuitenkin tarvittavan tiedon ja asiantuntijuuden uudelleenarviointia, oppijoiden kysymysten omistajuuden lisäämistä sekä kykyä edetä ennaltamäärittämättömillä tavoitteilla, ja koko yhteisö mukaan ottaen.

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In Helsinki, November 2019

Jaana Herranen

CONTENTS

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following publications:

I Herranen, J. Kousa, P., Fooladi, E., & Aksela, M. (2019). Inquiry as a context-based practice – a case study of pre-service teachers' beliefs and implementation of inquiry in context-based science teaching. *International Journal of Science Education, 41*(14), 1977–1998.

II Herranen, J., & Aksela, M. (2019). Student-question-based inquiry in science education. *Studies in Science Education, 55*(1), 1-36.

III Herranen, J., Vesterinen, V-M., & Aksela, M. (2018). From learner-centered to learner-driven sustainability education. *Sustainability, 10(*7), 2190.

IV Herranen, J., Tolppanen, S., Vesterinen, V-M., & Aksela, M. (2020, in press). Challenges and tensions in collaborative planning of a student-led course on sustainability education. *Nordina, 16*(1), 18-36.

The publications are referred to in the text by their roman numerals.

Acknowledgment is given to the journals for publishing the publications.

Author' s contribution to the publications:

I: Author was involved in planning the study, gathering and analysing data, and writing the article. Author was responsible in putting the article together to be published.

II: Author was involved in planning the study. Author was responsible for gathering and analysing data, and writing the article.

III: Author was involved in planning the study, gathering data, and writing the article. Author was responsible in analysing data.

IV: Author was involved in planning the study, gathering and analysing data, and writing the article. Author was responsible for the publishing process of the article.

ABBREVIATIONS

e.g.	exempli gratia
ESD	Education for Sustainable Development
etc.	et cetera
GT	Grounded Theory
LC	Learner-Centred
LD	Learner-Driven
NOS	Nature of Science
PCK	Pedagogical Content Knowledge
SSI	Socio-Scientific Issues

1 INTRODUCTION

According to the global climate report, the temperature of our climate has been increasing worryingly (NOAA National Centers for Environmental Information, 2018). Thus, recent years have seen increasing interest in raising awareness over sustainability issues and how to tackle them in several fields. Education has been deemed as important, because future citizens need to tackle and cope with the challenging issues and conditions caused by generations before them. However, it is not evident, which skills are needed, and therefore there are different views of the goals for sustainability education. Chemistry has been seen as contributing to both causing as well as solving the challenges. Chemistry, for example, plays a significant role, because industry of many of the products we use, is based on chemistry (Burmeister & Eilks, 2012), and naturally life itself is based on chemical processes. Issues, such as the production of energy and different goods, are linked to both sustainability and chemistry (Burmeister & Eilks, 2012). Through green chemistry safer chemicals, and other key research areas are developed (Anastas & Kirchhoff, 2002). To be able to address the issues in the chemistry class, teachers need skills, knowledge and appreciation over sustainability and science. Furthermore, it has been suggested that teacher education should be reoriented (UNESCO, 2005) for demands of the quickly changing world. Sustainability education has its challenges as well, including for example uncertainty, complexity and interdisciplinarity (Barth & Michelsen, 2013). Thus, approaches have been developed and are being developed that have the potential to improve sustainability in chemistry education. As an example, inquiry-based education and life-cycle analysis have been suggested to be used as approaches in sustainability education (e.g. Juntunen & Aksela, 2013). There are also models for science teacher education recommending explicit sustainability education through contents, contexts and methodology of chemistry, but also sustainability skills (Jegstad & Sinnes, 2015).

It has been suggested that instead of transmitting (sustainability) knowledge to the students, they should become transformative thinkers (Tilbury & Wortman, 2008), being involved with shaping their education (Grandin, 2011). In practice, the students could be offered possibilities to make decisions on what and how they learn. In this view, students are seen as active participants of the society, who have action-competence to take action in their own lives (Mogensen & Schnack, 2010). In science education, students' active role in learning has been considered as important, which is highlighted in skills that the students are hoped to acquire through their education, such as

scientific literacy, to be able to use scientific thinking in their own lives as well as in their society (American Association for the Advancement of Science, 1989). Thus, approaches that enhance students' activity are called for, and different forms of learner-centred pedagogy have emerged that view students as active learners. Moreover, also teachers, researchers, and practically each citizen in our society is understood as a learner. One typical learner-centred pedagogy used in science education is inquiry-based learning. Open inquiry has been used as one way to carry out such inquiry-based learning, in which the students pose questions and plan and carry out their inquiries on those questions. The importance of addressing and using the students' questions in sustainability education, have been highlighted before (Tolppanen & Aksela, 2018). In addition, to connect science learning to the students' own lives, context-based teaching has been suggested to be used (e.g. Gilbert, 2006; Sevian, Dori, & Parchmann, 2018) as a form of humanistic approach (Aikenhead, 2006), also in inquiry-based learning.

However, also challenges and concerns have been brought up, when students have been given more role over educational decision-making. Some educators fear that they would lose control if they stopped lecturing (e.g. Felder & Brent, 2010). The quality of learning has also been questioned, for example when using peer-tutoring (Topping, 1996). Yet another concern relates to the views and beliefs of student teachers on key issues of science and sustainability education. Crawford (2014) has brought up a concern over student teachers' simplistic views about inquiry in science education. In addition, there are studies arguing that student teachers have insufficient knowledge on what comes to sustainability, such as on environmental knowledge (see e.g. Alvarez-García, Sureda-Negre, & Comas-Forgas, 2018). To take these concerns into account, beliefs and practices about inquiry-based science education, sustainability education and learner-driven education are studied in this thesis to understand some of the possibilities and challenges of a learner-driven science teacher education as a phenomenon.

This thesis continues the research conducted in the Unit of Chemistry Teacher Education, where learner-centred teacher education has been developed as a research-based practice (Aksela, 2010), and where one point of focus is education for sustainable development for student teachers as part of their chemistry teacher education (Aksela, 2016). In addition, the strategy of the University of Helsinki has brought the student in the centre as they are considered to be part of solving the challenges of tomorrow (Strategic plan of the University of Helsinki).

The aim of this thesis is *to understand the possibilities and challenges of learner-centred and learner-driven science teacher education for sustainability*. Rationale of this research is to understand learner-centred and

learner-driven science teacher education for sustainability from the point of view of those that carry it out now – teachers (**study II**), and those who could carry it out in the future – student teachers (**studies I, III** and **IV**) in order to improve teacher education without pre-defining the goal of education. In this sense, this thesis approaches student teachers' learning from the point of view of 'Bildung' (see e.g. Sjöström, Frerichs, Zuin, & Eilks, 2017), considering student teachers' learning as an open and flexible process. Although models for sustainability education in chemistry have been created for teachers (Jegstad & Sinnes, 2015), and there is research on the meanings that higher education students give to learner-centredness (Lea, Stephenson, & Troy, 2003), research on learner-driven science education and especially promoting sustainability is scarce.

The research questions are:

R1: Which possibilities do learner-centred and learner-driven approaches offer to science teacher education for sustainability?

R2: What are the challenges of learner-centred and learner-driven science teacher education for sustainability?

To answer the research questions, four studies were conducted (see Figure 1). **Studies I**, **II**, **III** and **IV** give information of the possibilities of learner-centred and learner-driven approaches. The challenges are addressed in the **studies II** and **IV**. **Studies I** and **II** study the possibilities of inquiry with student teachers (**study I**) and using students' questions as a starting point for inquiries in different educational levels as a learner-driven inquiry approach (**study II**). **Studies III** and **IV** give information on the possibilities of learner-centred and learner-driven sustainability education. The challenges are discussed in the **studies II** and **IV** from the viewpoint of using students' questions in inquiries (**study II**) and from the viewpoint of student-led sustainability education (**study IV**). In that case, the students are higher education students, and most of them student teachers.

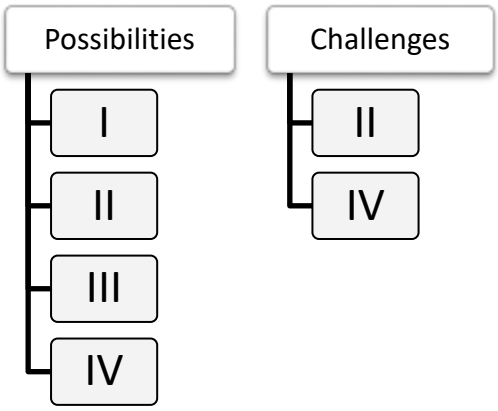

Figure 1 The connection between research questions and studies I, II, III, and IV.

Three of the studies are case studies aiming to understand the phenomenon, learner-centred and learner-driven science teacher education for sustainability, in-depth. **Studies III** and **IV** use data of a student-led sustainability education course planning. The planning is studied using grounded theory to understand students' beliefs about learner-centred and leaner-driven approaches (**study III**), and discourse analysis to understand the discourses of the challenges and tensions of student-led sustainability education (**study IV**). **Study I** studies a case of chemistry student teachers who planned their own context-based inquiry teaching sequences. Their beliefs about inquiry and their implementations of inquiry are studied using discourse analysis. **Study II** is a systematic review of research and reported practices conducted in 2008–2017 on using students' questions in inquiry (student-question-based inquiry). Systematic review was chosen as a research method in that study as it gives a holistic picture of the teachers' possibilities of using students' questions in inquiries.

The following chapters, two, three and four, present the background of this thesis. Chapters two and three introduce sustainability and inquiry in science education, especially from a learner-centred and learner-driven point of view, in which students' activity to learn and act in their community is important. In addition, the connection between science and sustainability education is addressed briefly. Chapter four introduces learner-centred and learner-driven education in general and connects it to science teacher education.

The background sections are followed by descriptions of how the multi-method research methodology of this thesis was chosen and used (chapter five), and their inherent reliability and validity issues (chapter six). Chapter seven describes the setting of the studies, which is important especially when three of the studies are case studies. Chapter eight summarises the results one

research question at a time. These results are then discussed in chapter nine to summarise and analyse how they can be utilised as implications for research on learner-driven education and in the development of learner-driven science teacher education for sustainability. Thus, although both learner-centred and learner-driven approaches are discussed throughout the thesis, particular emphasis is put on the learner-driven approaches in teacher education for sustainability, and hence also reflected in the thesis title.

For clarity, it should be noted that different types of students are referred to in this thesis; students in school, higher education students in the universities and student teachers as such higher education students who study to become teachers (pre-service teachers). Learner is used as a term when discussing about learning in general, in any school level or even out of school. The term is also chosen, because it is active, positioning the student as a learner, rather than being a passive receiver of education. In **study IV**, term student-led is used to describe the kind of teaching, that is run by students, instead of teachers.

2 SUSTAINABILITY EDUCATION

Due to environmental and more recently societal concerns over the future of our planet and societies, environmental education (Dillon, 2014) and later education for sustainable development and sustainability education emerged. Despite of decades of addressing sustainability and sustainability education issues, how to define those is still under debate. This is because of multiple perspectives connected to them (Wals & Jickling, 2002). This chapter introduces some of those perspectives, and especially those connected to the active role of the learners, in this case, their action-competence.

2.1 SUSTAINABLE DEVELOPMENT AND SUSTAINABILITY

In the 1970's, the terms sustainable development and sustainability appeared in research literature (Dillon, 2014). Although the term sustainable development has many different definitions (Johnston, Everard, Santillo, & Robèrt, 2007) influenced by different worldviews (Giddings, Hopwood, & O'Brien, 2002), the most well-known and used one is the Brundtland commission's definition from 1987. According to that definition, sustainable development is: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission of Environment and Development, 1987). It is widely used, although it has also been criticised (Johnston et al., 2007). Especially how "development" should be understood, and whether the term should be used at all, has been under discussion. It has been suggested, for example, that we need to define development from the human point of view, instead of the economical point of view (Johnston et al., 2007). There have also been discussions on whether to give priority to preserve development or nature (Dillon, 2014). It has been suggested that the components of sustainable development, ecological, societal and economical, could be combined in a way that takes into account the multi-layeredness by combining the societal and the economical component (Giddings et al., 2002).

Alongside with the term sustainable development, sustainability has been used as a term, where the idea of development as a goal is excluded. Although, sustainability is also seen as a blurry term (Johnston et al., 2007), the definition depending on the context and application of sustainability (Weisser, 2017), Wals and Jickling (2002, p. 9) have pointed out that "the fact that

'sustainability' is a messy, ill-defined concept gives universities an opportunity to grapple with the concept and develop new ways of thinking about the concept". In other words, the lack of a clear definition can be used as an asset, not as a barrier when working with sustainability issues. Wals and Jickling (2002) described the complexity of sustainability as follows:

> *Sustainability is as complex as life itself: The concept of sustainability is related to the social, economic, cultural, ethical and spiritual domain of our existence. It differs over time and space and it can be discussed at different levels of aggregation and viewed through different windows. Hence, a curricular review in terms of sustainability integration is per definition of an interdisciplinary, systemic and holistic nature. It concerns cognition, attitudes, emotions and skills. It does not lend itself to unilateral, linear planning or a reductionist scientific paradigm and thus involves the systemic integration between theory and practice into systemic praxis. (p. 7)*

In national curricula, for example that of Finland, the term sustainable development is used (The Finnish National Board of Education, 2014). According to the curriculum, students should learn about sustainable ways of life, such as sustainable consumption. Sustainable future, global education and sustainable use of natural resource are also mentioned, as well as different components, ecological, societal and the economical component, of sustainable development. Chemistry's role for a sustainable future is emphasised as securing the wellbeing of the environment and humans through developing new solutions. Students should be guided to evaluate their own choices from the viewpoint of sustainable use of natural resources and the lifecycle of a product (The Finnish National Board of Education, 2014).

2.2 PROMOTING SUSTAINABILITY EDUCATION

There are different views about the goals and methods of sustainability education (e.g Vare & Scott, 2007), which are reflected on what are seen as possibilities and challenges of it. The possibilities include e.g. use of specific pedagogy, for example, inquiry-based learning (e.g. Juntunen & Aksela, 2013), but also challenges related to pedagogy, content and structures as Tolppanen and Aksela (2018) described in their study on climate change education. A concern has been raised over teachers lacking both theoretical knowledge as well as practical ideas on how to carry out sustainability education (Burmeister, Schmidt-Jakob, & Eilks, 2013).

Although sustainability education is in many cases referred to as education for sustainable development (ESD), the term "for" has been criticised, because we do not know yet what a sustainable world looks like (Wals & Jickling, 2002). Still, ESD has largely been used as a term to describe practices, which are not in contrary to the ideal of the emancipatory approach for sustainability. For example, it has been suggested that ESD should highlight the whole community of learners for example by encouraging participatory decision-making involving teachers, students and researchers (Burmeister, Rauch, & Eilks, 2012; Rauch, 2004). ESD should also be interdisciplinary and learner-centred (e.g. Burmeister et al., 2012). In addition, ESD has been shown to be effective in learning about sustainability (Boeve-De Pauw, Gericke, Olsson, & Berglund, 2015).

Challenges include opposing views on the primary goal of sustainability education. These views can be referred to as the instrumental view, concentrating on giving well thought solutions to sustainability problems (Sterling, 2010), and the intrinsic view, which highlights critical thinking skills to solve complex problems of sustainability (Vare & Scott, 2007). Both of these approaches have their benefits and challenges. The instrumental view might be supported as environmental problems need to be solved urgently. This approach is in line with the idea that sustainability education should be about, for, and contributing to sustainable development. These goals are reflected most highly in a model according to which chemistry education is considered as a part of ESD-driven school development (Burmeister et al., 2012). On the other hand, the intrinsic view takes into consideration the fact that the future is unknown. Therefore, pre-determined solutions to the problems might not exist. In addition, an instrumental, an eco-totalitarian view might result in more sustainable living, but an intrinsic, emancipatory approach might result in action-competent citizens, who are happy and thus capable of responding to emerging environmental issues (Wals & Jickling, 2002).

It has been stated that sustainability education should be transformative (Sterling, 2001; Blackie, Case, & Jawitz, 2010), including futures thinking, negotiation, and self-initiated action (Tilbury & Wortman, 2008). The skill to negotiate is connected to the social component of sustainability education. These include for example participatory action, urge towards democracy, and citizenship skills (Burmeister et al., 2012). Those skills are important as sustainability issues are wicked and require multidisciplinarity.

Promoting the ability to act and contribute to sustainability is seen as necessary when addressing sustainability issues. The competence to act and feel empowered is central in improving student participation (Paloniemi & Koskinen, 2005). That is, students need action-competence which according to Mogensen and Schnack (2010) highlights:

- focusing on enhancing teaching and learning
- supporting democratic values of ESD
- collaboration with several stakeholders to elaborate quality criteria for action
- promoting individual as well as institutional learning

Thus, action-competence should, according to Mogensen and Schnack (2010) be seen as an educational ideal, similar to what has been referred as the German notion of 'Bildung', a perspective that views learning as a continuous and open-ended process, where no fixed solutions exist, and where learners are seen as active, democratic citizens (Mogensen & Schnack, 2010). At the heart of this approach is promoting critical thinking to deal with power relations and conflicting interests to evoke empathy and appreciation of different perspectives, and to think of alternative actions and opportunities (Mogensen & Schnack, 2010). Along with critical thinking, systems thinking and futures thinking are seen as important (e.g. Burmeister et al., 2012). Because the components of sustainability are interconnected (Wheeler, 2000), how these components should be taken into consideration as part of decision-making for a better future, in turn requires understanding of the possibility of different futures and skills to reflect and manage changes (see e.g. Paige & Lloyd, 2016).

What constitutes "good" action for sustainability is, however, unclear. Actions to solve global problems, such as climate change, are essential (Burmeister et al., 2012). For an individual, dealing with such socio-scientific issues (SSI) is not necessary within immediate reach (Burmeister et al., 2012). In addition, action as individual learning might be different from action for the community, as the learner might give priority to learn e.g. skills for their own use without considering their usefulness for the benefit of the community. However, this comes down to how learning is defined. Bildung for one, typically views learning from individual in society –point of view (Sjöström et al., 2017), thus giving emphasis on individual's learning and growing as an active and thinking citizen.

In teacher education, sustainability has been considered to be necessary (Aksela, 2016), but challenging to include in (Firth & Winter, 2007). Teacher education in Finland has also failed to include sustainability in adequate extent, for example because teacher education is based on separate disciplines (Wolff, Sjöblom, Hofman-Bergholm, & Palmberg, 2017). However, Jegstad and Sinnes (2015) created a model for chemistry teacher education in which aspects of ESD for chemistry teachers were considered to be related to both chemistry; chemical content knowledge, chemistry in context, and the

distinctiveness and methodological character of chemistry, as well as to ESD; ESD competences and lived ESD.

To sum up, sustainability education should promote action, reflected by the individual (Rauch, 2004) and the community (Mogensen & Schack, 2010) to support learning as a joint effort of our societies.

2.3 THE CONNECTION BETWEEN SUSTAINABILITY AND SCIENCE EDUCATION

Issues of sustainability and science/technology are connected (see Figure 2), because "science shapes, and is shaped by, sustainability" (Miller, 2013, p. 281). Firstly, understanding and applying science and technology is required for promoting sustainability (Feinstein & Kirchgasler, 2015), and many of the products that we use are based on chemistry (Burmeister & Eilks, 2012). In order to make sustainable products, understanding and skills of both sustainability and chemistry are required. In essential, although chemistry can contribute to unsustainability through unsustainable industry, a chemistry positive discourse takes a stance as chemistry being part of the solution, not the problem.

Secondly, discourses in sustainability raise issues, needs, to be solved using science and technology (Feinstein & Kirchgasler, 2015). In their essay, Feinstein and Kirchgasler (2015), however, argue that science education might offer too simplistic perspectives to address issues such as climate change, and does not take societal and ethical aspects into account on a sufficient degree. Addressing important global issues requires knowledge from the field of social sciences seeking to understand social systems and cultures, for example (National Research Council, 2012).

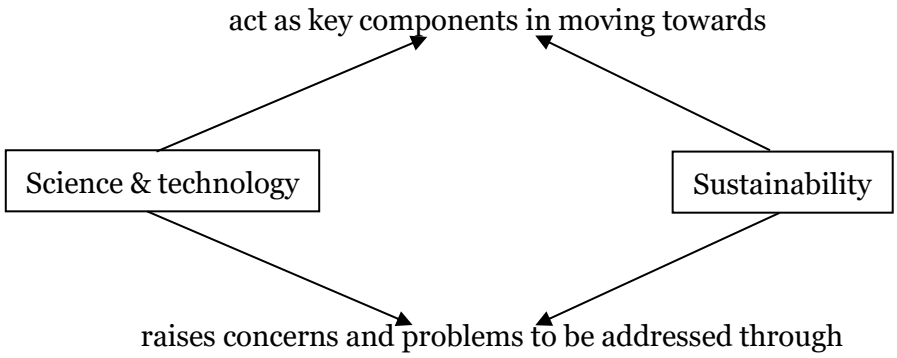

Figure 2 The connection between science and sustainability (based on Miller, 2013).

What this connection means for science education can be discussed by taking a multidisciplinary approach. Feinstein and Kirchgasler (2015) suggest that science educators and social studies educators could join their forces and utilise pedagogical approaches from both fields. They are afraid that the solutions for global issues, such as climate change, are discussed currently in the school from merely the point of view of science, and normative or political changes that indirectly influence climate would receive little attention.

Another approach commonly introduced is the use of SSI as a pedagogical strategy (Sadler, 2011) through e.g. inquiry-based approaches and interdisciplinarity (Juntunen & Aksela, 2014). The benefits of using SSI in ESD are:

- learning of and applying scientific content knowledge in a societal context
- improvement of skills to think moral and ethical aspects
- increased student motivation for chemistry learning
- improved understanding of the importance of science for everyday life and society (Juntunen & Aksela, 2014)

3 INQUIRY-BASED SCIENCE EDUCATION

Inquiry-based practices have been promoted as central in science education for more than a century. However, teachers and researchers have a wide variety of beliefs about inquiry and its use as a pedagogy in teaching (see e.g. Luft, 2001). This chapter introduces some of the discussions about inquiry, and especially describes two approaches in which learners are actively involved in their own learning by placing them in a social context using context-based approaches, and in which they learn by asking questions that could be used in inquiry teaching.

3.1 BELIEFS ABOUT INQUIRY-BASED SCIENCE EDUCATION

Despite the wide use of inquiry-based teaching in science education, there are still various meanings associated with the word "inquiry" (Bevins & Price, 2016; Crawford, 2014; Rönnebeck, Bernholt, & Ropohl, 2016). Inquiry can be viewed through its goals (Abrams, Southerland, & Evans, 2008): learning about inquiry, learning to inquire and learning science content through inquiry. When defined by the user of inquiry, the terms scientific inquiry, inquiry learning and inquiry teaching, can be used (Anderson, 2002). Scientific inquiry is carried out by scientists, inquiry learning is something that the students can do, and inquiry teaching includes ways in which teachers can use inquiry as a pedagogical tool (Anderson, 2002). There are also other topics that in many cases complement and overlap with inquiry, such as Nature of Science (NOS) (e.g. Abd-El-Khalick et al., 2004) and argumentation (e.g. Duschl & Osborne, 2002). It has also been used within specific topics, such as those connected to sustainability (see e.g. Juntunen & Aksela, 2013).

In addition, teachers hold manifold beliefs, views and conceptions about inquiry (e.g. Breslyn & McGinnis, 2012; Brown, Abell, Demir, & Schmidt, 2006; Luft, 2001). Inquiry and open inquiry are used as synonyms in many cases (Brown et al., 2006). Open inquiry is a type of activity that starts with the students' questions (Banchi & Bell, 2008). In guided inquiry, the teacher gives the students a question, which the students use to plan and carry out an inquiry. In structured and confirmatory inquiry, the teacher gives the students questions and execution instructions, and the students follow the instructions to get results (Banchi & Bell, 2008). Thus, in open inquiry, the students get more freedom than in the more closed versions of inquiry.

Despite the importance of using inquiry teaching in the school emphasised for example in national curricula (see e.g. The Finnish National Board of Education, 2014), concerns have been raised over student teachers' simplistic views of inquiry (Crawford, 2014). However, research indicates that teacher education can have an effect on the type of inquiry teachers use in the school. For example, significant undergraduate or professional experiences from authentic research was shown to advance the teachers' open and guided inquiry choices (Windschitl, 2003).

3.2 CONTEXT-BASED APPROACH FOR INQUIRY-BASED EDUCATION

There has been increasing interest in shifting the focus of science education from subject-centred perspective towards more humanistic approaches, according to which the students' learning should be connected to their lives outside school, so they would learn things that are useful for them as future citizens (Aikenhead, 2006) to become lifelong learners. Context-based learning is one possibility through which the humanistic approach can be taken into account. Use of contexts, preferably from everyday life, has been claimed to make learning more meaningful as the content is learned form need-to-know-basis (Bulte, Westbroek, de Jong, & Pilot, 2006), thus supporting positive science attitudes, and link what is learned to other contexts as well (Gilbert, Bulte, & Pilot, 2011).

Context-based approach (e.g. King, 2012; Klassen, 2006) and its connection to inquiry (Glynn & Winter, 2004) has been conceptualised in several ways. Context can be understood as a place, such as a laboratory in which science is practiced. Themes and topics, such as food and cooking (Fooladi, 2013), or the environment (King & Henderson, 2018) have been used in science education to connect content into something meaningful and to give examples (Gilbert, 2006). Context is, however, more than a physical place or a theme of the lecture. It is, in its best, something that takes the social situation and the related language into account (Gilbert, 2006). This is in line with the idea that science in itself is practiced in a context and interacts with the community. "Contexts enable students to experience competence and social embeddedness, not just within but also outside the classroom, by becoming able to apply school knowledge to relevant topics in the real world" (Sevian et al., 2018, p. 1097).

Gilbert (2006) has framed context as a setting, which has its specific social and behavioural characteristics, such as an ice cream factory. King and Ritchie (2013) have described context as a location, which has certain structure and

resources, such as a location in which the students take a water sample. In both of these descriptions, language plays a significant role: as terminology of ice cream making (Gilbert, 2006) or conversation between concepts and context (King & Ritchie, 2013). Indeed, Gilbert (2006) has suggested that in order for the students to transfer knowledge into practice, they need to participate in the social context.

3.3 STUDENTS' QUESTIONS IN INQUIRY-BASED SCIENCE EDUCATION

In a typical science classroom, the teacher is often the one who asks the questions. There has also been increasing interest in using students' questions for teaching as they benefit both the student as well as the teacher (Chin & Osborne, 2008). Students' questions can direct inquiry practices (Crawford, Kelly, & Brown, 2000), and the students' have been shown to enjoy inquiring into their own questions (Chin & Kayalvizhi, 2005). Learners' questions are also important when they construct knowledge (Chin & Chia, 2004). Students' questions therefore support both motivational as well as cognitive aspects of teaching and learning. Chin and Osborne (2008, p. 2) have explained the importance of questioning by stating that: "A key, if not central, feature of scientific discourse is the role of questioning in eliciting explanations, postulating theories, evaluating evidence, justifying reasoning, and clarifying doubts."

Despite all the benefits of using students' questions in teaching, they are not necessarily used in schools because of social, cultural, and institutional reasons (Chin & Osborne, 2008). Students have been shown to lack appreciation of their own questions (Rop, 2003). There has also been a concern over students' questions being too shallow (Graesser & Person, 1994) or unusable without modification (Roth & Roychoudhury, 1993). It has been claimed that students should know something about the topic to be able to ask good questions (Miyake & Norman, 1979). However, the concept of a "good question" is unclear. According to Chin and Osborne (2008), one type of question is a "researchable question" so the quality of the question is determined by how researchable it is. That is, how scientific it is.

Two main approaches to use students' questions can be identified. Firstly, the students can be promoted to ask certain types of questions, for example researchable questions. According to a review by Chin and Osborne (2008), the teachers can plan instruction with that goal in mind. For example, in the study by Cuccio-Shirripa and Steiner (2000), it was shown that the students, who had received instruction on how to ask researchable questions, could

formulate such questions better than the control group. Secondly, the students can be encouraged to ask questions in general. Use of students' questions in teaching has, in fact, been claimed as a student-centred activity (Pedrosa de Jesus & Moreira, 2009). This approach has the potential to direct learning from the students' point of view, fostering discussion in the classroom, helping the students in self-assessment, and supporting motivational aspects (Chin & Osborne, 2008). This allows the teacher to evaluate students' thinking and the chosen classroom activities, and use the questions in open investigations, in problem-based learning and in project work (Chin & Osborne, 2008).

Addressing learners' questions is important in sustainability education, e.g. climate change education (Tolppanen & Aksela, 2018). Students' questions should be addressed holistically taking into account several aspects, such as the technological and societal aspect, and guided inquiry could be used as a pedagogical approach to work with the questions (Tolppanen & Aksela, 2018). The relation between students' questions and context-based education has been studied by Swirski, Baram-Tsabari, and Yarden (2018).

4 LEARNER-CENTRED AND LEARNER-DRIVEN SCIENCE TEACHER EDUCATION

This chapter introduces two different perspectives for developing science teacher education, supporting teachers' pedagogical content knowledge (PCK) (Shulman, 1986), and re-orienting teacher education through perspectives of Bildung. Subsequently, learner-centred and learner-driven education and practices previously being connected to them are introduced.

4.1 STUDENT TEACHERS AS LEARNERS

Besides being a teacher, a teacher is also a learner (Loughran, 2002). Behind such a teacher as a learner approach, in line with the idea of constructivism, is that along with the students, also teachers learn all the time (Loughran, 2002). Thus, student teachers are navigating on the road from a student to a teacher. According to Wallace (2003), conditions for teacher learning are that learning about teaching is i) situated, such as in authentic teaching situations, ii) social by participating in discussions, and iii) distributed, meaning that teacher's work is distributed to the community such as other teachers. At the heart of this list is collaboration and the willingness to learn.

Discussions over what the student teachers should learn during their education, are in many cases held within the concept of pedagogical content knowledge (PCK), including aspects of both content and pedagogy (Shulman, 1986). It has been suggested that, in addition to teaching student teachers how to teach established science content, science teacher education should take into consideration currently relevant issues, and how to manage still unknown issues of tomorrow — the issues of the 21st century through developing skills. These skills include i) life and career skills, ii) key subjects and 21st century themes, iii) learning and innovation skills, and information, media, and technology skills (Framework for 21st century learning, 2007). Especially relevant in teacher education are the learning and innovation skills: creativity and innovation, critical thinking and problem solving, communication, and collaboration (Framework for 21st century learning, 2007). According to Bell (2016), sustainability ought to be acknowledged into 21st century skill frames as well. Sustainability pedagogical content knowledge has been studied previously by Jegstad and Sinnes (2015).

How teacher education is developed, depends on its goals. The aforementioned approach enhances the relevant knowledge and skills that the

teacher should gain. Opposed to that, in sustainability education, there has been discussions over an intrinsic view (Vare & Scott, 2007) and transformative learning (Sterling, 2001), according to which the future is unknown and therefore we do not yet know which content to teach to the students. This is also in line with the notion of Bildung (Mogensen & Schnack, 2010, see chapter 2.2), according to which solutions for what to learn are not fixed, but are seen as possibilities for action reflected amongst several stakeholders. Especially for student teachers, learning through reflective practice, is important (Loughran, 2002).

Because the position of student teachers is somewhere between the student and the teacher, such teaching and learning methods have been suggested for teacher education that acknowledge this need and potential for student teachers to practice teaching and reflect on it. One of these methods is a peer teaching model according to which student teachers assume the role of teachers to teach their peers in a collaborative reflective process (Vesterinen & Aksela, 2013). Thus, peer teaching may not only provide practice in teaching, it also supports learning. This kind of learning by teaching has been shown to support, for example, development of 21st century skills amongst the science student teachers (Aslan, 2015).

4.2 LEARNER-CENTRED AND LEARNER-DRIVEN SCIENCE EDUCATION

In recent years, attention has been given to learners as active participants, giving rise to terms such teacher-led, student-centred, student-led, and learner-driven. In learner-centred education, the idea is that learner is at the centre, not the topic being taught, and thus, the voice of the learner should be given a more prominent position (Paris & Combs, 2006). The students are encouraged to be active concerning their own learning and influence the community they are in (Cook-Sather, 2014; Fielding, 2011). The approach has been claimed to support students' motivation to learn, depth of understanding, and appreciation of the subject they are taught (Felder & Brent, 1996).

Learner-centredness is rooted in the constructivist learning theory, where learning is conceptualised as an active pursuit that learners undertake in order to learn. The learners have responsibility and autonomy of their own learning, and through their active role, the learners are assumed to enhance deep learning and understanding. The teacher is also in an important role, because the teacher and student are dependent on each other, and have mutual

appreciation of their relationship. (Hannafin, Hill, & Land, 1997; Lea et al., 2003; Paris & Combs, 2006).

In addition, challenges have been brought into attention while using learner-centred approaches. It requires flexible time tables, as the schedule cannot be predefined by the teacher, and adequate resources. In addition, the teacher and the other students should support the learner, the teacher should be approachable and enthusiastic, learner has to have personal motivation over the topic and the ability to carry out self-directed working, know what to do and have self-discipline, and not feel left alone. (Lea et al., 2003)

In practice, many approaches have been described as learner-centred or learner-driven. A summary of typical approaches are given in Table 1, although the list is not exhaustive of all possible learner-centred or learner-driven approaches.

Table 1 *Examples of learner-centred and learner-driven learning approaches.*

Learning approach	Description of the approach
Flexible learning	A guided choice offered to the learners, typically in higher education, to decide upon the time, pace, place, content, style, assessment, and collaboration related to their learning activities (Ling et al., 2001).
Experiential learning	Effective learning occurs when the learners finish the experiential cycle of learning, the components of which are: concrete learning, reflective observation, abstract conceptualization and active experimentation (Kolb, 1984).
Self-directed learning	Learners take responsibility and collaborative control over their learning. Learning is constructed through cognitive and contextual processes. (Garrison, 1997)

Table 2 *Examples of learner-centred and learner-driven learning approaches continued.*

Learning approach	Description of the approach
Inquiry-based learning	Learning through actively engaging with resources (environment, people, literature) to generate or answer questions or solve problems. Different levels of learner participation. (Abrams et al., 2008)
Project-based learning	Learning organised around realistic projects that the learners carry out with great level of autonomy. Projects are driven by questions and carried out by investigations. (Thomas, 2000)
Relevant-topic based learning (or context-based learning)	Use of everyday life issues in science teaching (Kang & Keinonen, 2018), social aspect being important (Gilbert, 2006)
Discussion-based learning	Learner-learner and learner-teacher discussion (Kang & Keinonen, 2018), in which the participants share their thinking and reasons behind that thinking (Shemwell & Furtak, 2010).
Question-based learning	Use of learners' questions as a recourse for science learning and teaching, such as in inquiries (Chin & Osborne, 2008).

The descriptions are examples of how learner-centred approaches have been described, but there are naturally also other possible definitions and views not addressed here. The approaches found from the literature are flexible learning, experiental learning, self-directed learning (O'Neill & McMahon, 2005), project-based learning (Thomas, 2000), inquiry-based learning, relevant-topic based learning, discussion-based learning (Kang & Keinonen, 2018), and question-based learning (Pedrosa de Jesus & Moreira, 2009). To which degree the approaches are learner-driven, depends on their use in practice. In inquiry-based learning, the level in which the students ask their own research questions, plan and practice inquiry, is called open inquiry (Buchanan, Harlan, Bruce, & Edwards, 2016), which is essentially learner-driven. In the

context of chemistry, learner-driven approaches include approaches in which the learners develop something, such as green chemistry experiments (Graham, Jones, Schaller, & McIntee, 2014).

Learner-centred learning approaches described in Table 1, however, overlap in some cases. For example, project-based learning can be viewed as one way to carry out inquiry-based learning (Crawford, 2014). In addition, question-based learning can be connected to inquiry (Chin & Osborne, 2008), but it can also be a part of project-based learning at least, because a project can be driven by questions (Thomas, 2000).

5 METHODOLOGY

Because the aim of this thesis is to understand the possibilities and challenges of learner-centred and learner-driven science education for sustainability, qualitative approach was chosen as a research methodology. Because each study in this thesis has its unique set of research questions, different qualitative methods are used in each study. This is, therefore, a qualitative, multi-method research in which several qualitative methodologies and methods are used (see e.g. Silverman, 2000), especially suitable for case studies that form an important part of this thesis (Bassey, 2000; Hamilton, 2018). Qualitative research prefers naturally occurring data and studies people's behaviour and the meanings they give to their behaviour (Silverman, 2000). Qualitative research typically uses an inductive approach (Silverman, 2000), which is also applied in this research, together with deductive and abductive reasoning. Along with the case-study approach, also systematic review is used in this thesis. Data is analysed using both grounded theory and discourse analysis (see Table 2).

Table 2 *Research methods used in the thesis.*

	Study I	**Study II**	**Study III**	**Study IV**
Research method	case study, discourse analysis	systematic review, discourse analysis	case study, grounded theory	case study, discourse analysis
Data	reports, semi-structured interviews	peer-reviewed articles	conversations, semi-structured interviews	conversations, semi-structured interviews

Multi-method research combines either quantitative or qualitative methodologies (Silverman, 2000). Using multiple methodologies in qualitative research aims to give a fuller picture of the phenomenon (Denscombe, 2014), although there is a concern over treating social reality different ways when using different methodologies (Silverman, 2000). In this research, social reality is viewed as being constructed by people in social situations, and language is used to express thinking, feelings and experiences. This thesis, therefore, follows a constructive/interpretive research paradigm,

and the studied reality is understood as a creation of people's experiences, culture and the context they are part of (Treagust, Won, & Duit, 2014). To develop understanding of learner-driven science education and sustainability education as a construction of reality by the people involved in science and sustainability education, qualitative methods are used to gather and analyse in-depth data. Data includes interviews, writings as reports and research papers, and discussions.

5.1 CASE STUDY

Educational case studies empirically study a chosen case, a naturally occurring phenomenon (Denscombe, 2014). It has been defined as a study of a real-life phenomenon in its context, and typically when the phenomenon and context are intertwined (Yin, 2014). It has also been verbalised as a study of instances of action (MacDonald & Walker, 1975), or a study of a system (Stake, 1995). It is a study of an individual or a group or groups of people, such as a school class (Cohen, Manion, & Morrison, 2007), so it has boundaries (Denscombe, 2014). In this thesis, a course (**study I**) or a planning of a course (**studies III** and **IV**) create those boundaries.

There are many ways to approach and categorise case studies (e.g. Yazan, 2015) out of which this thesis follows mostly the approach by Stake (1995). Stake has categorised case studies as either intrinsic or instrumental. In an intrinsic case study, the researcher is interested in the case itself and aims to describe it in detail, and in an instrumental case study, the interest is in understanding a phenomenon and choosing the case or cases accordingly (Stake, 1995). In this thesis, an instrumental approach has been applied as the research aim that guided the choosing of cases. Case study is a suitable approach for small-scale projects, which is one of its benefit. It is also holistic, uses naturally occurring events as data source and facilitates the use of multiple methods (Denscombe, 2014). The main disadvantage of case study is in its generalisability. However, validation of data can be addressed through triangulation (Stake, 1995).

5.2 SYSTEMATIC REVIEW

Reviewing primary research can be used as a tool to inform us about "what is known, how is known, how this varies across studies, and thus also what is not known from previous research" (Gough, Oliver, & Thomas, 2012, p. 3). Systematic review is a systematic and evidence-based way to conduct such a review (Petticrew & Roberts, 2006), and can be used to summarise either

quantitative or qualitative studies (Denscombe, 2014). In this thesis, qualitative research has been conducted to understand the meaning of the phenomena under study (Gough et al., 2012). However, comparing, evaluating and synthesising findings in qualitative systematic review is challenging (Denscombe, 2014). In this thesis, that challenge is taken into consideration by utilising the method narratively (Denscombe, 2014) describing the uses of students' questions in inquiry (**study II**).

Systematic review continued the work carried out before on students' questions (Chin & Osborne, 2008), therefore suggesting categories for future research on the topic. Thus, deductive content analysis (Hasni et al., 2016) was used to analyse the reports. Systematic review includes the following steps (Denscombe, 2014): i) deciding on the topic, ii) searching for articles from multiple sources, iii) evaluating quality in terms of relevance, that is, including only articles that meet the set criteria, and quality which is in this case taken into consideration by choosing only peer-reviewed articles and moreover summarising key findings only from research articles, iv) listing sources, including inclusion and exclusion of articles, v) writing a descriptive summary, vi) analysing the reviewed articles, in this case narratively. On one hand, emerging themes were recognised from the articles on linguistic level (thematic synthesis), and on the other hand, the underlying causes were identified on why and how the articles obtained their findings and arguments on the use of students' questions in inquiry (realist synthesis). The last step is to write the conclusion, which is presented as a model, according to the deductive content analysis model that is used (Hasni et al., 2016).

Systematic review gives the researcher a possibility to summarise and critically analyse the research topic holistically. However, the challenge is that the research findings in a qualitative systematic review are more difficult to evaluate than in quantitative systematic review as they are likely to be more varied. To offer a larger scope on the actual practices, also peer-reviewed evaluative and descriptive reports were included in increasing the practical value of the review, although those reports might have quality issues in terms of research conducted. Therefore, research findings were summarised only from the research reports.

5.3 GROUNDED THEORY

When a new phenomenon is studied in order to develop a theory about that phenomena, grounded theory (GT) can be used as a research method. In GT, empirical research data is gathered and analysed to develop theory rather than testing it (Denscombe, 2014), so that the theory would be grounded in the data

(Glaser & Strauss, 1967). However, according to the straussian perspective, the researcher's background might have an influence in the analysis (Corbin & Strauss, 2008). Taking this into consideration, the approach values theoretical openness, not fixed ideas about the studied setting (Denscombe, 2014). Reasoning in GT is abductive as theory is based on empirical data, which is used along with known theories to make an interpretation of the studied phenomenon (Dey, 2004). GT is generally used in qualitative and small-scale research aiming to produce theory for practical use (Denscombe, 2014). GT was used in **study III** to develop a theory about the studied phenomena, learner-centred and learner-driven sustainability education from point of view of students' beliefs. In the article, a case study approach was used, and GT was used as the methodology to analyse data. For this purpose, all course designing meetings were recorded and the students were also interviewed in the middle and end of the process.

The analysis included three phases: open coding, axial coding, and selective coding (Corbin & Strauss, 2008). In this thesis, the open coding phase was carried out twice: the first round was used to retrieve codes including the term student-centred (or learner-centred) and student-driven (or learner-driven), and the second round was based on the sub-categories of the first round. This was done to understand the student teachers' beliefs about the concepts more in-depth, and the kinds of ideas they connected to learner-centred and learner-driven sustainability education. When analysing data, the constant comparative method was used to compare codes and categories (Glaser & Strauss, 1967).

5.4 DISCOURSE ANALYSIS

Discourse analysis is used to analyse text and talk in social situations, and it can be used with for example interviews or naturalistic data (Hepburn & Potter, 2004). As the ontological premise in discourse analysis is that reality is socially constructed, it was considered as a suitable research method for the studies in this thesis. Discourses are viewed as something, which are both constructed by the culture we are part of, and something that create our culture (Remes, 2006). Discourse analysis therefore approaches language and social situations as a culture. Discourses are on one hand considered quite stable, but on the other hand, they change along time (Remes, 2006).

In this thesis, the results of the case studies, using discourse analysis (**studies I** and **IV**), analytically generalise results to other resembling contexts in this point of time. This thesis argues that the discourses that are found or created within the research, do not only limit to the studied

situations. They reflect on the discourses that exist in sustainability education (**study IV**) or inquiry-based science education (**study I**). **Study IV** argues that the challenges found through the analysis are connected to wider discourses on the tensions of sustainability education. This approach requires the use of abductive reasoning as the inductively found challenges are connected to the discussion and literature on the topic (previous theory). This type of reasoning stems from grounded theory (Dey, 2004), but examples of combining inductive and deductive reasoning has been reported by e.g. Fereday and Muir-Cochrane (2006). In addition, in **study I**, the inductively and deductively found categories and themes were connected to previous research on beliefs and implementations of inquiry, thus applying abductive reasoning.

Discourse analysis can be approached from three different traditions: empirical, rational, and pragmatic (Remes, 2006). Linguistic tradition is empirical and concentrates on texts and language (Remes, 2006), therefore typically referred to as content analysis. In this thesis, **studies I** and **II** used content analysis. **Study I** used it both inductively and deductively. In the first phase, student teachers' texts were analysed inductively to form codes and categories, and in the second phase, those codes and categories were used deductively to analyse how they exist in their reports. In **study II**, deductive content analysis was used as existing categories were used to study the student-question-based approach in inquiry in the reviewed articles at a linguistic level. **Study IV** concerned the meanings behind spoken language and utilised a rational approach to discourse; it is descriptive of texts used in their context (Remes, 2006).

5.5 INTERVIEWS

In studies that aim to understand a phenomenon in a deeper level from people's point of view, such as their opinions or experiences, interviews are typically used (Denscombe, 2014). Interviews can be conducted with different levels of structure, depending on how much freedom of speech is given to the interviewees (Denscombe, 2014). In addition, one person can be interviewed at a time (one-to-one interview), or a group of people (group or a focus group interview).

Conducting an interview is challenging as data might be affected by the researcher's personal identity, their interviewing skills and the venue of the interview (Denscombe, 2014). This requires practice and careful planning of the interview.

In this thesis interviews were used in **studies I, III,** and **IV** as semi-structured interviews, as the goal was to chart the interviewees' ideas on certain topics, but also to allow them to express all issues that they were thinking about the topics. **Study I** was conducted as one-to-one interview, because we were interested in the beliefs of the individual student teachers. In **studies III** and **IV**, the entire planning group was interviewed as understanding their planning process as a group was one of the aims guiding the study.

6 RELIABILITY AND VALIDITY

In qualitative research, reliability and validity issues are addressed differently than in quantitative research. Validity expresses how accurately the results represent the studied phenomena, and reliability expresses the degree of consistency (Silverman, 2000). Validity was taken into account using the constant comparative method, comprehensive data treatment, using appropriate tabulations, and during analysis, deviant-case analysis (Silverman, 2000). In addition, also triangulation and in-depth descriptions were used in the case studies (**studies I, III,** and **IV**) as suggested by Stake (1995).

The constant comparative method originates from grounded theory (Glaser & Strauss, 1967). Therefore, it has been used rigorously in **study III**, in which the codes and categories were compared during coding. Also, in other studies (**I**, **II,** and **IV**), coding units, codes, and segments of data were compared in the analysis.

The constant comparative method has similarities to comprehensive data treatment as the original data set is revisited during the analysis to ensure that the findings are in line with the results as a whole (Silverman, 2000). The principle was used as far as was considered adequate. However, it would have been possible to use an even bigger portion of data in the studies. For example, in **studies III** and **IV**, there would have been more data of the planning process available in the course platform, but going through that data showed that it would not add relevant information to the key results.

When reflecting on the whole thesis, triangulation was taken into consideration in this thesis using the multi-method approach (Denscombe, 2014). Specifically, methodological and data triangulation has been used. Methodological triangulation was achieved in **studies III** and **IV** which studied the same higher education student group. **Study III** used grounded theory and **study IV** discourse analysis as a research method. Those studies used planning records as well as interviews as data sources. Therefore, the accuracy of the interviewees' comments could be compared with their comments during planning meetings and vice versa. Theory triangulation was also used as **study III** concentrated on the theory of learner-centredness and **study IV** on different theories about sustainability, sustainability education and collaboration. Triangulation within an article is strongest in the review article (**study II**) (Petticrew & Roberts, 2006).

Limitations of this thesis are mostly related to the used case study approach as the results are not necessarily generalisable (e.g. Yazan, 2015). However,

the aim of case studies is in many cases to understand or describe a chosen phenomenon (Denscombe, 2014), which is also the aim of this thesis.

Ethical considerations are connected to the research methodology used. In the studies involving making records of the higher education students (**studies I**, **III**, and **IV**), the students were explained and asked for a consent to study their discourses during their planning meetings and interviews, and literal expressions in their written documents. Research data was treated with confidence and acronyms were used from the students to ensure anonymity.

7 RESEARCH SETTING

This thesis consists of four studies in three settings. Inquiry-based education is studied in **studies I**, and **II**, and sustainability education in **studies III** and **IV**. In this section, the research settings of those studies are described.

7.1 THE COURSE "INQUIRY-BASED CHEMISTRY EDUCATION II"

The setting of the **study I** was the course "Inquiry-based chemistry education II" and the student teachers attending that course. The course was arranged at the Unit of Chemistry Teacher Education as a compulsory undergraduate course for chemistry student teachers. The course consisted of theory and practice on inquiry- and context-based teaching. After participating in lectures and practices, the student teachers planned and tested their own context-based inquiry teaching sequences with students aged 13–15.

Five out of six student teachers in the course participated in the study. They had chemistry as their first teaching subject, and mathematics as their second, besides one student teacher who had mathematics as their first subject and chemistry as the second. They had attended "inquiry-based chemistry education I" prior to the course studied, but no other inquiry-based courses.

A short task "What is inquiry?" was designed to capture the features of inquiry. For the task, they were supposed to read a book chapter on the topic (Abrams et al., 2008), and write a short text with free format. Furthermore, their reports on the planned inquiry teaching sequences, where they could choose context of their interest, were studied to understand how they chose to implement those features of inquiry in practice. Student teachers planned the sequences in pairs or individually, and course teachers tutored the student teachers during planning. Student teachers were also interviewed by semi-structured interviews after the course on their beliefs about inquiry- and context-based teaching, among other things.

7.2 REVIEW OF THE STUDIES ON USING STUDENTS' QUESTIONS IN INQUIRIES

Study II concentrated on how students' questions have been used in inquiries in recent years, and therefore, a systematic review was carried out. The studies (n=30) were research reports, descriptive reports and evaluative reports.

Some of the studies explicitly addressed using students' questions in inquiry-based teaching and other reports described that as an approach.

The reports were mostly on science education in general, not on certain disciplines. Most of them were studies of secondary education and primary education, but also other education levels were present. The topics varied from forests to gas chromatography.

The studies mostly studied students' questioning skills as a part of some other activity, or in some structured form. In many studies, the students were guided to formulate certain types of questions. The reviewed studies did not concentrate only on student learning. Also the teacher was sometimes studied.

7.3 THE COURSE "SUSTAINABLE DEVELOPMENT IN EDUCATION"

The setting for **studies III** and **IV** was the course "Sustainable development in education" tested for the first time at the Unit of Chemistry Teacher Education. The course was part of the project ActSHEN (Action for sustainability in higher education in the Nordic region), which had the goal of improving higher education students' active participation in their sustainability education. Five higher education students were interviewed and chosen to plan and run the course "Sustainable development in education" for other higher education students as an intensive two-week course in 2015.

In both **studies III** and **IV**, the planning process of a higher education student group was studied to understand their beliefs about learner-centred and learner-driven education (**study III**), and the challenges and tensions in planning the course as a multidisciplinary collaboration (**study IV**). The researchers helped the group with practical issues but their ways of working as a group, the pedagogical decisions, and content choices were up to the group to decide. The planning sessions were audiotaped, transcribed and analysed. The group was also interviewed in the middle and at the end of the course. Group's planning was intense: they planned using Moodle and meeting face-to-face, and they also travelled to CEMUS (Centre for Environment and Development Studies in Sweden) to exchange ideas about student-led sustainability education. The group consisted of higher education students who were either studying as teachers (student teachers) or interested in teaching. Two out of five students dropped out of the planning process due to challenges in schedule and planning, but their discussions are part of the empirical data as it gives insight on the challenges and tensions of student-led planning.

8 RESULTS

In this section, the results of this thesis are summarised from the studies (see Table 3). The results are addressed one research question at a time.

Table 3 *Possibilities and challenges of learner-centred and learner-driven teacher education for sustainability.*

Possibilities	**Challenges**
Inquiry-based education	
Learner-centred approach to student-question-based inquiry: teacher can guide and support the question-formulation before the inquiry with several methods, such as teaching content, skills and giving a driving question (**study II**)	Learner-centred approach to student-question-based inquiry: teacher's guidance can be challenging in terms of actual ownership of questions (**study II**)
Learner-driven approach to student-question-based inquiry: Use of students' questions in inquiries as an approach to support students' ownership of their questions (**study II**)	
Learner-driven approach to inquiry: student teachers can plan context-based inquiry teaching sequences in which several relevant aspects of inquiry are addressed **(study I)**	
Sustainability education	
Learner-centred and learner-driven approaches are fundamentally different in terms of learners' roles. In learner-driven education, learners drive learning (**study III**)	Student-led approach: different views of sustainability content, pedagogy, process and roles (**study IV**)
Student-led course planning on sustainability education is possible, and the discourses during planning mirror the discussions in research literature (**study IV**)	

8.1 POSSIBILITIES OF LEARNER-CENTRED AND LEARNER-DRIVEN SCIENCE TEACHER EDUCATION FOR SUSTAINABILITY

Each study in this thesis revealed different aspects of the possibilities of learner-centred and learner-driven education. The possibilities were studied in relation to inquiry-based education (**studies I** and **II**) and sustainability education (**studies III** and **IV**).

Study I "Inquiry as a context-based practice – A case study of pre-service teachers' beliefs and implementation of inquiry in context-based science teaching" studied the case of student teachers' beliefs about inquiry and its implementations in an inquiry-based chemistry teaching course. The case was chosen as it represents the phenomenon under study from point of view of inquiry-based education, which is common in science education, but also from the point of view of a learner-driven practice, in this case when the student teachers planned their context-based inquiry teaching sequences.

The study resulted in understanding about student teachers' beliefs about inquiry, and descriptions about their implementations of inquiry and context within the inquiry. Student teachers' beliefs about inquiry were shown to reflect manifold and complex understanding of inquiry, such as inquiry as an activity, a way to teach and learn that there are multiple understandings of inquiry, that it is difficult to explain what inquiry is, and that inquiry provides connections between science and society. The most frequent implementations of inquiry were connected to inquiry including a context, being a way to think and act, and including source/information evaluation and argumentation. Student teachers were shown to be able to design context-based inquiry teaching sequences, which had aspects of inquiry that were closely linked to the aspects of inquiry discussed in the research literature. However, context was described differently in each of the reports of teaching sequences. Context was described as a place, a topic and as a social practice. What was in common in all of the teaching sequences was, that context-based inquiry was seen to be as a learning goal for the teacher in which students make observations and collect data in order to use the knowledge of the topic and ways to inquire in everyday life or in creating something new. As a result, context-boundness of inquiry was seen in student teachers' reports and interviews.

Possibilities for inquiry were also studied in **study II** "Student-question-based inquiry in science education", in which student-question-based inquiry practices were hypothesised to be learner-driven. The aim of the study was to review i) on the significance of questions in inquiry ii) the key findings of student-question-based inquiry, iii) the practices, and iv) the teachers' and students' roles in it.

As a result, a model for student-question-based inquiry was obtained. The model represents the significance of questions in inquiry, the possible goals for inquiry (according to the key findings), and the possibilities of questions before and during inquiry. The significance of questions is that they drive and direct the inquiry, which was seen as a scientific practice but also pedagogy. The possible goals include inquiry and questioning skills, but also thinking and discussion skills, as well as differentiation, motivational aspects and scientific knowledge. According to the results, the teacher has many opportunities to plan and carry out question-based inquiry. Before the inquiry, students can learn or be taught about the content and inquiry, they can be given a driving question and the questions can be formulated, negotiated and modified. During the inquiry, the questions can be answered, inquired, discussed and formulated as the inquiry proceeds. According to the study, teacher guidance is central in the studies related to student-question-based inquiry.

Study III "From learner-centred to learner-driven sustainability education" studied a case of higher education students' beliefs about learner-centred (LC) and learner-driven (LD) sustainability education, when they planned the course "Sustainable development in education" to understand what learner-centred and learner-driven sustainability education is, from their point of view. The case was chosen, as the hypothesis was that it would give insight to the studied phenomenon of this thesis, as the student planning group would have to discuss about various aspects related to sustainability and sustainability education. The group consisted of higher education students who were either studying as teachers or interested in teaching. The group planning discussions and two semi-structured interviews make up the case that was studied. The planning of the course was student-led, but the group was not told what the participants' role should be – how learner-centred or learner-driven. Therefore, it was hypothesised that they would also have to discuss about the participant's roles, and that the participants' roles would be discussed using different terms.

The study gave understanding about higher education students' beliefs about LC and LD in sustainability education, and about the learners' roles therein. As a result, the differences of the approaches were identified. According to the students' beliefs, LC sustainability education is a method for learning and teaching in which the learners have some freedom and they participate in the learning environment, but the teacher decides the goals, defines sustainability, considers learners' differences and supports the students in learning and acting for sustainability. LD sustainability education, on the other hand, is divergent pedagogy, in which learners have freedom in deciding goals, and their learning is driven by their interest and what they find relevant. The learners make an influence on the learning environment and

define sustainability, and the teacher acts as a facilitator in the learning environment.

8.2 CHALLENGES OF LEARNER-CENTRED AND LEARNER-DRIVEN SCIENCE TEACHER EDUCATION FOR SUSTAINABILITY

While the possibilities for learner-centred and learner-driven science education were studied in previous studies, a hypothesis was that there would also be challenges, especially in the case of planning the student-led course. Those challenges were investigated in **study IV**. Challenges of learner-centred approaches were also visible in **study II** on using the students' questions in inquiries.

Study IV utilised the same case as **study III**, investigating the challenges that higher education students faced when they planned the sustainability education course. In addition, tensions underlying those challenges were recognised.

The study showed that the course designers had to deal with five interrelated challenges, which included defining sustainability, seeking the focus of education for sustainability, deciding how to implement sustainability education, figuring out their own role, and finding agreement on how to make decisions during collaborative educational planning.

These inductively derived observations were examined in the light of previous discourses on collaborative sustainability education, named as tensions. The tensions were human development vs. environmental conservation, affective vs. cognitive focus, participatory action vs. critical discussion, peer role vs. expert role, and drive towards unanimity vs. agreeing to disagree. As a result, it was stated that the studied higher education student group was discussing the prominent issues, tensions, of collaborative sustainability education, which are also discussed among the researchers.

In addition to the possibilities, **study II** also revealed challenges of the approach. The challenge is the actual role of the learner. Although students' questions were used in the reported practices in many cases, the teacher determined the interventions, the topics, the resources and the driving questions for the students. This raises a question of the ownership and autonomy of students' questions. It is also an issue of power relations if the question the learner asks, is not considered "good enough" for investigations. In addition, in some of the practices, questions of only some students were used in inquiries, possibly resulting in inequality in terms of whose questions are worth answering or inquiring and whose are not.

9 DISCUSSION AND CONCLUSIONS

This section discusses the central argument of this thesis. This thesis has argued that learner-centred and learner-driven approaches are different constructs, with possibilities and challenges. Studies showed that higher education students were capable to plan teaching sequences and a course, during which they recognised relevant aspects of the topic. Challenges were shown to be connected to e.g. learners' roles. Finally it is argued that more learner-driven approaches could be implemented in science teacher education to achieve sustainability.

9.1 POSSIBILITIES OF LEARNER-CENTRED AND LEARNER-DRIVEN SCIENCE TEACHER EDUCATION FOR SUSTAINABILITY

To be able to discuss learner-centred and learner-driven approaches, it is important to have some kind of agreement what we mean by the terms. Although learner-centred pedagogy has been discussed widely in the literature (O'Neill & McMahon, 2005), the spectrum of views and approaches has been quite vague in order to be able to discuss the terms specifically. As a result of **study III**, a clear distinction has been made between learner-centred and learner-driven education. According to the results, LD approach differs from the LC approach fundamentally. In brief, learner-driven education is an approach, not just a teaching method. Learners are involved in their learning in the LC approach, but LD learning requires more radical shift of power relations as the teacher gives more freedom and autonomy for the learners to decide their actions as in the LC approach. Therefore, the discourse on the topic revolves around the roles of students and teachers as well as goals of education. What is the students' role in terms of learning towards sustainability? What is the necessary amount of involvement? The different approaches are summarised in Table 4.

Table 4 *Differences between learner-centred, learner-driven and student-led approaches. Student: a person who participates to a course, teacher: a person who is in charge of the course, student as a teacher: a student who plans and runs a course.*

	Learner-centred	**Learner-driven**	**Student-led**
Teaching and learning is planned	by the teacher	by the students as teachers or a participant	by the students as teachers
Learners' interests	are taken into consideration	drive learning	have a role depending on the students as teachers
Learners' activity	is high	is high	depends on the students as teachers
Role of the teacher	is to plan and carry out learner-centred teaching	is to facilitate and mentor	is to facilitate and mentor on a degree depending on the students as teachers

This thesis has also contributed to the discussion of educational ideals and goals. In **study III** it was found that goals are set differently in the LC and LD approaches. They have probably also been developed with different goals is mind. In the LC approach, the teacher sets the goals, and in the LD approach, the goals are set by the learners. The goals are not predefined in the LD approach, but the learners are engaged in a process of reflecting on how sustainability relates to themselves and to their learning, and set goals accordingly. In **study I**, student teachers set goals, but also indicated their beliefs on which aspects they thought to be important although not explicitly stated as goals. Those aspects were more like by-products, or secondary goals. Goals in the LD approaches might also have to be flexible to be able to allow participation of several stakeholders and a longer goal setting process influenced by learning processes. This kind of flexible goal setting could be seen in **study IV**. **Study II** examined the possibilities of using students' questions in inquiry-based science education. Two approaches with different goals were revealed: student-question-based inquiry as an inquiry teaching method, in which the teacher guides the learners in their question-formulation, and student-question-based inquiry as an approach in which the inquiry is actually directed by what the students ask. The first of these

approaches can be categorised as learner-centred, as the students are actively involved in teaching. The second approach can be called as learner-driven, because the learners drive learning, instead on of being merely involved in formulating the questions. The discussion of these two approaches is connected to the competing discussions described throughout this thesis, such as discussions over skills versus Bildung or an instrumental or an intrinsic approach. Student-question-based inquiry as a teaching method promotes the students to learn skills to formulate questions, preferably what are conceived as "good questions" by the teacher. Student-question-based inquiry as an approach is characterised by promoting the students to ask questions as part of their growth as thinking, democratic, and literate citizens in a way that is not predefined by the teacher.

The discourses in learner-centred pedagogy are connected to knowledge, construction of knowledge, and ownership of knowledge. Learner-driven inquiry is in line with social-constructivism as knowledge is constructed by actively engaging and affecting on the learning processes resulting in ownership of knowledge. In the study on student-led planning, the higher education students decided to use experts indicating their doubt about their own knowledge of sustainability. However, it would be useful for future teachers to feel at least some ownership of sustainability knowledge because they teach sustainability issues in school. There should be more discussion on the ownership of sustainability knowledge in general.

Despite of the possibilities of both learner-centred and learner-driven approaches, review of the literature implies that sustainability education should be learner-driven as it supports the individual's learning towards sustainability. Firstly, humanistic approaches operate from a need-to-know basis, and individual's learning is based on what is relevant for them to know in their own lives (Aikenhead, 2006). **Study I** also showed that inquiry is context-bound, and a context-based approach requires the use of extra-situational knowledge from the context, not only declarative knowledge bounded by science. Calabrese Barton, Lim, and Tan (2008) have suggested that science could be seen as a context rather than a goal. According to this view, science learning should be expanded also outside the science class to connect science in the students' lives. Viewing science as a context makes it possible to have flexible learning goals as the processes and products are not pre-defined.

Secondly, learner-driven approaches are in line with the intrinsic view (Vare & Scott, 2007), according to which the future is unknown and thus relevant actions as well, including how education should be. The urgency of addressing environmental issues is, however, a challenge of this approach, as

described in the background. Constant reflection between actions and critical analysis of the required actions is a possible approach.

It has also been suggested that sustainability education should be transformative (Sterling, 2001). Further, as discussed in **study III**, transformative education can be seen as connected to capabilities approach (Lozano, Boni, Peris, & Hueso, 2012) emphasising persons' own motivation and agency instead of fixed knowledge and demand-oriented learning. The approach is connected to the Bildung perspective for action-competence described by Mogensen and Schnack (2010).

According to the results of this thesis, learner-driven approaches could also be possible for teacher education, as it not only supports student teachers' learning, but also the learning of their peers. It was shown that higher education students can plan student-led courses for their peers (**study III**), and that they were able to recognise relevant aspects of the issues they were about to teach (**studies I** and **IV**). In **study I**, student teachers' beliefs and implementations of inquiry were in line with what is discussed about inquiry in the literature. Interestingly, student teachers had difficulties in explaining inquiry although they could discuss it in the interviews and use it in their teaching sequences. This finding suggests that a clear-cut definition is not necessary in order to be able to use inquiry as a concept. This is important when considering which are the requirements of student-led education are. It could be studied more in the future, which aspects students need to be able to define prior to teaching their peers, and which aspects can remain undefined. In addition, the influence of not defining concepts in teacher-led education is a possibility for future research.

According to this thesis, learner-driven education could support action-competence. As described by Mogensen and Schnack (2010), building action-competence is an open, continuous process with several stakeholders. Based on this research, it is argued that student teachers could be seen as relevant stakeholders for acting in higher education for sustainability, as it is possible for them to carry out such teaching sequences and courses in which they take different relevant aspects of the topic into account in their discussions and plans.

9.2 CHALLENGES OF LEARNER-CENTRED AND LEARNER-DRIVEN SCIENCE EDUCATION FOR SUSTAINABILITY

A challenge of learner-centred science education was identified in this thesis, as well as challenges linked to learner-driven science education. Although not

explicitly studied, a challenge of the ownership of questions was identified in **study II**. In many cases the questions are probably actually owned by the teacher or the other students, because the teacher, for example, sets driving questions for the students (Weizman, Shwartz, & Fortus, 2008) or the questions used are negotiated with the other students, possibly affecting some of the students never getting answers to their questions (Cavagnetto, Hand, & Norton-Meier, 2010). This is a concern if teaching supports the participation of some of the students, while some students are left out. All students should have the possibility to participate in the community of practice (Gilbert, 2006). Students should feel that their questions are appreciated and that they can use their questioning skills to learn. Empowerment to not only act but to learn is crucial in learning sustainability.

The teachers' ownership of the questions might be explained by the authority the teacher wishes to keep or the perceived knowledge over "good" and "bad" questions. Instead of using those terms, a term "investigative question" could, for example, be used to describe the use of question for a specific purpose. This affective means could motivate students, as their questioning skills in general are not judged. This study argues that learner-driven approaches for inquiry-based learning are more than just a method. It is an ideology of giving the students actual ownership of the questions by using students' questions in inquiries.

Study IV specifically concentrated on those challenges connected to student-led collaborative planning. Identified challenges were further seen to relate to tensions underlying those challenges. The tension discourses are also present in sustainability and collaborative education, and this study showed that higher education students can be aware of those tensions affecting on their discussions and the planning process.

The identified challenges were connected to sustainability and its education, the roles of the higher education students planning the course and how they should work as a group. One central issue in the discussions is how knowledge and different views are perceived. According to this study, views of the goals of sustainability education can be connected but still separate.

In creating sustainability knowledge, multiple ways of knowing are appreciated (Miller, Muñoz-Erickson, & Redman, 2010). Therefore, it is important to learn to agree to disagree. Decision-making could be practiced in teacher education to support the idea of multiple ways of knowing, which is important due to the wicked nature of sustainability issues.

Discussions over sustainability knowledge is connected to the discussion over ownership of that knowledge. The discourse on the roles and particularly on the expertise is interesting as it also touches upon the general discussion on expertise in sustainability education. Especially teachers' lack of confidence

to teach sustainability (e.g. Papadimitriou, 2004) and insufficient pedagogical content knowledge over sustainability education (Burmeister et al., 2013) has been brought up. However, whether addressing these deficiencies should be seen as the primary goal for educational development, is another issue. Involving students into the process could be an option, but it requires a change of perspective. We need to re-define how we see teaching and learning.

9.3 ADDRESSING THE CHALLENGES, UTILIZING THE POSSIBILITIES

In light of the identified challenges in this study, a shift towards more learner-driven science education could take time. A gradual change might be easier to achieve than changing everything at once.

Open inquiry and other learner-driven approaches can be misunderstood for lacking structure or guidance. However, teachers' support is important, and LD approaches can have some structure. The time frame can, for example, be given to the learners. In **study II**, one presented idea was that the students first learn something, then they pose questions, and finally their questions are used in inquiries. In addition, it must be noted that there are various ways to include learners' questions. It can be carried out as a more closed form of inquiry rather than open inquiry. The students can pose questions, which can be used to plan inquiries with the teacher. Therefore, to address the challenges of using students' questions, the formulation of the questions can be seen as a joint effort. In general, the social aspect of learning is essential in learner-driven approaches. As discussed in study I, the social aspect of inquiry (see e.g. Chin & Osborne, 2008) might help in making the inquiry process more authentic as ideas of several students can be utilised.

Study IV raises a question about the reasons for the identified challenges. Students in higher education have different backgrounds, personalities and goals, which might influence their different views on sustainability education. Why this became a challenge might relate to the fact that the issue was important for the students.

Despite the challenges, **study IV** showed that higher education students could accomplish their planning and run a course. In fact, not all challenges can or even should be mitigated. It is important that the students can discuss various points of view, also the less-popular ones (e.g. Sterling, 2010). Trying to mitigate the challenges and decrease conflicts might affect the sense of autonomy and self-confident in solving things out for oneself. However, support should be given when needed. For continuity of LD courses, staff

support is crucial (e.g. Almlöv & Moberg, 2008; Hällström, 2011). In addition, the use of mentors (e.g. other students) can be a good way of offering support.

9.4 IMPLICATIONS FOR TEACHER EDUCATION

The results of this thesis can be utilised in teacher education. Critical discussion and practical approaches can be used to develop higher education towards sustainability. We need to ask ourselves what we are teaching the students for. As summed up in the theoretical background, sustainability education should understand action-competence as a flexible and continuous process. Learner-driven science teacher education towards sustainability has the potential to support such action-competence. Involving student teachers in educational decision-making is imperative as teachers directly influence future generations. Learning to participate in educational decision-making could help teachers to use participatory learning methods in their own teaching. By becoming aware of the possibilities of participation (e.g. Bovill & Bulley, 2011), teachers can re-examine the roles of the students and the teacher in their own teaching, and possibly make changes to learning arrangements.

Learner-driven, collaborative planning can give students a possibility to practice new ways of thinking. How well it corresponds with such thinking skills that are considered crucial in terms of sustainability, such as systemic, critical or futures thinking, depends on the learners and their mentors (such as teachers). In a learner-driven approach, the teacher cannot have such a straightforward influence on the students' learning outcomes. Instead, the students might learn different things. However, the same issue is inherent in learning disciplinary content knowledge. On the other hand, the possibly learn issues more deeply and might have more relevance to the students' own lives. Actually, to achieve learner-driven science teacher education, which is in line with the humanistic approaches and sustainability, extra-situational knowledge as described in **study I**, used resources, such as textbooks require a critical evaluation on how they are used. Other resources, those outside the science class (Calabrese Barton et al., 2008), could offer possibilities, perspectives, knowledge, and contexts to support Bildung.

Learner-driven science teacher education promotes collaboration especially when students plan teaching together. In the courses, studied in this thesis, higher education students worked in groups. It was shown that students in higher education could, in cooperation, plan courses. They can discuss their different views and consider them during planning. According to this thesis, they are able to take different aspects of inquiry-based learning and sustainability education into account in their teaching plans. Co-teaching is a

possible model for learner-driven education, and could also be used in schools, as sustainability education requires multiple approaches. To what extent can the students take a part in planning their education? Research and development in this area needs more attention. It would be especially interesting to study this approach at various school levels, such as in secondary school.

Limitations of this thesis are related to the case study approach used. In addition, because most of the studies were conducted in higher education, more studies on how to implement learner-driven approaches in school could be studied. Nevertheless, this thesis contributes to the understanding of some of the possibilities and challenges of learner-centred and learner-driven science teacher education towards sustainability. Science teacher education and the institutions offering that education could see student teachers as relevant stakeholders in actions towards sustainability, and they could seek ways to utilise and continue researching on learner-driven education.

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